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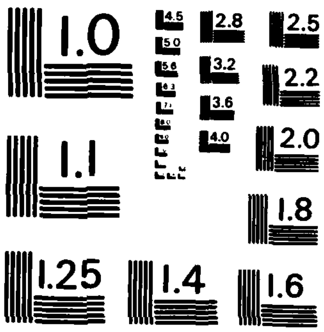

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A MODEL FOR ESTIMATING NAVY MANPOWER IN BASE OPERATING SUPPORT PROGRAMS

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A MODEL FOR ESTIMATING NAVY MANPOWER IN BASE OPERATING SUPPORT PROGRAMS

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The primary objective of this effort was to develop manpower estimating equations to forecast aggregate requirements within the base operating support (BOS) sector of Navy manpower. These statistical relationships should contain direct measures of the ship or aircraft forces that are resident at BOS locales. An extensive data collection effort was conducted so that data on the physical size and population supported by a given BOS activity could be matched with data describing the workload imposed by ship and aircraft forces resident at the activity. Multiple regression analysis was then used to obtain

estimating equations that are both statistically sound and intuitively appealing. Results showed that, for the major BOS categories of naval stations and naval air stations, manpower requirements were statistically related to both the manpower of the associated ship or aircraft forces, respectively, as well as to the tenant population of the "host" BOS activity. These findings did not vary by fleet nor were there significant differences among the various types (fleet, reserve, training) of air stations.

FOREWORD

This research and development effort was conducted in support of Navy Decision Coordinating Paper Z1186-PN (Impact of Fleet Configuration on Requirements for Support Manpower), subproject Z1186-PN.06 (Forecasting Long-range Manpower Requirements), under the sponsorship of the Deputy Chief of Naval Operations (Manpower, Personnel, and Training). The objective of this subproject is to develop long-range, aggregate manpower planning models to forecast Navy requirements for officer, enlisted, and civilian manpower.

This report describes the main effort conducted during FY 1981--the development of manpower estimating equations for the base operating support (BOS) sector of Navy manpower. The BOS manpower forecasting model has potential applications at the claimant and CNO programming levels. Currently, it can be used by manpower managers to test the effects of major changes in ship or aircraft forces on manpower requirements of two BOS activity groupings--naval stations and naval air stations.

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SUMMARY

Problem

The Navy does not currently possess an established analytic procedure for forecasting long-range manpower requirements. The specific area of base operating support (BOS), in particular, lacks a well accepted quantitative method of relating the manning requirements at shore activities to the varying force levels that these activities support.

Objective

The primary objective of this effort was to develop manpower estimating equations to forecast aggregate requirements within the BOS sector of Navy manpower. These statistical relationships should contain direct measures of the ship or aircraft forces that are resident at BOS locales.

Approach

To fulfill the ultimate objective, an extensive data collection effort was required so that data on the physical size and population supported by a given BOS activity could be matched with data describing the workload imposed by ship and aircraft forces resident at the activity. Multiple regression analysis was then used to obtain estimating equations that are both statistically sound and intuitively appealing.

Findings

For the major BOS categories of naval stations and naval air stations, it was found that manpower requirements were statistically related to both the manpower of the associated ship or aircraft forces, respectively, as well as to the tenant population of the "host" BOS activity. These findings did not vary by fleet nor were there significant differences among the various types (fleet, reserve, training) of air stations.

Conclusions

For the major BOS categories of naval stations and air stations, manpower requirements appear to be functionally related to the total population supported as well as to force-related variables. As the total population supported by these BOS categories and/or the force level increases, BOS manpower requirements should increase.

Future Direction

Prototype software for implementing the results of this effort will be developed and installed at computer facilities accessible by users (notably, OP-44 and relevant personnel within OP-01).

In addition, subsets of the historical data collected for this effort (e.g., host-tenant relationships, force levels and locations, and public works center data) will be documented and consolidated for possible use outside the BOS arena. In this way, the overall payoff from this reseach project can be maximized.

CONTENTS

LIST OF TABLES

INTRODUCTION

Problem

Forecasting the demand for manpower is one of the most critical problems facing Navy manpower managers. The Navy must refine its capability to (1) relate accurately manpower and personnel needs to active ship and aircraft inventories and (2) forecast military and civilian manpower requirements based on future force levels. Currently, to perform their roles, Navy manpower managers use an ad hoc combination of models, data bases, and simple manual calculations to analyze Navy manpower requirements 5 to 15 years in the future. In most cases, Navy planners must use large, detailed models and data bases that are operated primarily for near-term personnel and manpower accounting. Such tools have proven to be cumbersome and inefficient in a planning arena that requires rapid turnaround and analysis of many alternatives. Other more aggregate methods have been simplistic analytically and have been applied inconsistently from year to year by various Navy offices having an interest in long-range manpower requirements.

There is a definite need within the Navy for improved analytical methods, models, and data bases to support long-range manpower planning. Most importantly, there is a need for developing computerized models to forecast long-range support manpower requirements as a function of force levels, mix, operating tempo, and deployment patterns. Forecasting and justifying base operating support (BOS) manpower requirements have been especially difficult because of the diverse functions of BOS activities. The need to forecast and justify BOS manpower requirements is greater than ever as the Navy adds significant numbers of new ships and aircraft to the fleet.

Objective

The ultimate objective of the research program, of which the effort discussed here is a part, is to develop manpower forecasting models that provide a capability to estimate manpower requirements for the shore support establishment as a function of the size and characteristics of Navy force levels. These models will differ from any existing manpower planning systems in two ways. First, the focus is on an aggregation of support manpower in the major shore programs such as BOS, maintenance, supply, and training that directly support the fleet. This contrasts to estimations of manpower for activities broken down by specific functions such as those made by the shore requirements, standards, and manpower planning system (SHORSTAMPS). Secondly, these models are intended to be long-range, quick response planning instruments used to generate forecasts of manpower requirements for up to 15 years into the future.

With this general framework in mind, the immediate objective of the work described here is to develop a means to estimate manpower requirements in one major support area--base operating support. More specifically, the intent is to develop equations that estimate aggregate Navy manpower requirements at stations that support major Navy forces (ships and aircraft). The manpower requirements of these activities are expected to be strongly influenced by the size and characteristics of the forces using the BOS-provided services. The manpower estimating equations presented in this report will allow Navy manpower managers to project manning requirements for specific groups of BOS shore support activities, based on planned future force levels and characteristics.

Background

The current Navy planning process begins with the development of the Program Objectives Memorandum (POM) each May and requires analytic tools that can rapidly

provide information and accurately answer "what if" questions involving alternative force scenarios. Due to the necessity of timely information for this fast turnaround, existing Navy planning mechanisms have in some cases been inadequate because they have taken a simplistic approach in estimating manpower requirements for the POM and the biannual Five Year Defense Plan (FYDP) updates in October and January. The Navy Resource Model (NARM), using the OP-90 Management Information System (the POM data base), treats support sector manpower requirements as one-third fixed in all areas except BOS, where two-thirds is considered constant. The Extended Planning Annex (EPA) uses prorations and straightlining for out-year projections. Other manpower requirement estimating systems, such as SHORSTAMPS, present extremely detailed approaches that are not entirely appropriate for aggregate out-year manpower projection. Additionally, SHORSTAMPS does not cover all functional categories in areas such as BOS, and therefore cannot provide a complete picture of either the workload or the manpower requirements of entire support activities.

TECHNICAL APPROACH

Scope

BOS is defined by the Department of Defense as the resources used at installations, facilities, and activities to provide services to operational units and tenants so that they can perform their missions free of unrelated responsibilities. These services include functions such as grounds maintenance, housing facilities, building upkeep, transportation services, utilities, and minor construction projects. At the BOS activities that have been investigated, the workload generated by the population that is supported by the activity was examined and measured. This population includes the tenants of the facility and the forces that are either homeported or visiting a given location.

For the purpose of this investigation, the estimating equations for BOS manpower requirements address Navy (active officer and enlisted) and civilian personnel with no breakdown by grade or skill classification. The level of organizational detail for developing these manpower estimating equations is by groupings of unit identification codes (UICs), which represent sets of like BOS activities with respect to kinds of forces supported (e.g., naval air stations). The equations are developed by statistical analysis of historical data representing forces and the workload they place upon supporting BOS activities. This workload determines the amount of Navy BOS manpower and outside labor needed to provide the support services. Manpower data and workloads for major Navy BOS activities have been collected for 5 years and statistically analyzed to identify quantitative relationships between forces, workload, and support manpower. Even though these relationships are aggregate and based on historical data, in essence, they represent the de facto process the Navy has instituted for providing BOS manpower to support the operating forces. The data used to construct these equations have also incorporated programmatic variables such as the complexity and mix of forces, force size, and workload for the support establishment.

General Description of the Model

The following two groupings or submodels for BOS have been developed to date:

1. Naval Stations

   a. Naval Stations, Atlantic
   b. Naval Stations, Pacific

2. Naval Air Stations

   a. Naval Air Stations, Atlantic
   b. Naval Air Stations, Pacific
   c. Reserve Air Stations
   d. Naval Air Training Stations

Data bases were constructed separately for these two groupings. In addition, the ability to distinguish components within a grouping was preserved. For example, it was expected that the statistical analysis would yield different results for air training stations than for other naval air stations.

Throughout this report, the term "host" refers to any of the specific activities that fall within the BOS grouping as defined above. Tenants refer to the shore-based Navy installations (medical clinics, commissaries, air rework facilities, etc.) that receive support from the host activity. Appendix A displays the activities in the two groupings and the end strength for fiscal year (FY) 1979 associated with each activity.

The various workload data that were collected were compared with the population that was supported by each activity to determine the relationship between the two. As previously stated, this population included tenants using base-provided services and facilities and the force population that was resident there, either permanently or temporarily. Factors such as ship complexity, force mix, and force operating tempo were also considered to account for the characteristics of forces using base services. These relationships between forces and workload were computed and compared with historical manning of the BOS host activities to develop an empirically based estimating mechanism for use in calculating future support manpower needs dependent upon the size and characteristics of the supported populations and forces.

Data Aspects

Data Source Selection

To determine the kind and amount of data that should be collected concerning workload at the activities in the BOS groupings, Navy budget reporting systems used to justify BOS budget requests were examined. In the budgeting process, BOS funding is determined at the budget activity (BA) level, or, in some cases, at the claimant level, and is presented as such in the budget justification. These separate costs then feed into the line item, or functional category structure, and are presented in aggregate form in the Operations and Maintenance, Navy (O&MN) budget. In the budget justification, specific performance criteria are listed for these functional categories of BOS. Table 1 shows the functional categories for BOS and their associated performance criteria. These performance criteria were intially chosen as the workload data to be collected for the UICs (activities) in the groupings. They were chosen because they are standard reporting units used in the budget process, thereby tying the data used to construct the BOS manpower model to established Navy information systems. The underlying structure of a model so derived would also reflect the functional aspects of BOS manpower and interrelationships of these functions to force characteristics. Also, it was initially believed that data corresponding to each of these criteria would be readily available. It was thought that each BOS activity reports the information for each measure to their claimant, and the claimants then construct the aggregated program criteria. However, detailed investigation showed there is no central information system for activity or UIC-level information concerning these workload measures. In actuality, claimants provide some data at the activity level for BOS functions, but not specific workload-level indicators for individual

Table 1

Budget Functional Categories with Associated Performance Criteria

Functional Categories	Performance Criteria
Maintenance and repair of real property	Backlog of maintenance and repair Current plant value Number of buildings
Minor construction	Number of projects
Utilities	Electricity (MVH) Steam and hot water (TBTU) Potable water (MGAL) Sewage (KGAL)
Other engineering support	Floor area for custodial service Refuse/garbage disposal
Administration	Number of ADP central processing units owned Number of ADP automated systems
Retail supply operations	Number of line items carried Number of receipts Number of issues
Maintenance of installation equipment	Number of service craft/boat assigned Service craft/boat overhauls funded
Other base services	Number of vehicles maintained Number of vehicles miles driven Ships homeported-active
Bachelor housing operations and furnishing	BOQ capacity (man/month) BOQ utilization--average (man/month) BOQ capacity (man/month) BEQ utilization--average. (man/month)
Other personnel support	None
Morale welfare and recreation	None
Commissary operations	None
BOS aircraft operations	Average operating aircraft by type, flying hours by type, and aircraft cost by type and by hour
NATO infrastructure	Number of facilities by country Cost of facilities by country
Automated data processing (ADP)	Number of ADP CPUs leased Number of ADP CPUs owned Number of ADP automated systems
Audiovisual	None

UICs. Because data were not available at the UIC level for all workload measures, not all the performance criteria listed in Table 1 could be used in analysis.

Data Collection

Workload Data. Although no central information system exists for activity-level workload data, the Naval Facilities Engineering Command (NAVFAC) maintains a series of data systems controlled by the master activity general information control system (MAGIC). The MAGIC system contains general descriptive information for each UIC, such as location, tenants at the activity, and closest city. This system interfaces with numerous other data bases to retrieve specific UIC-level data on the services rendered and resources expended by the activity. From these data bases, the workload data needed to measure the amount and types of services provided by each support activity were obtained.

These data were all obtained by the same procedure, beginning with an intial meeting with the data base manager to ascertain the specific content of the system in question and verify its applicability and usefulness to the project. This was followed by meetings with personnel who dealt with the data system itself and then by a formal request either to have copies of tapes created or to permit access to hardcopy reports for manual retrieval of data. Initially, it was hoped that 10 years of historical data could be used, but constraints of the specific reporting systems permitted only collection of historical information back to FY 1976.

Each of the data systems from which workload data were taken is managed and maintained separately; therefore, each type of data had to be investigated and requested individually. Additionally, because each system is essentially a self-standing entity, not all data were available in tape form nor were all the historical system files kept for the same time frame. Much of the data had to be extracted by hand and transferred to tape.

Descriptive data about BOS facilities by activity, including the number of buildings, square footage of building space, and acreage of the naval station or air station, were obtained through tapes from the naval facilities assets data base. Utilities data concerning the consumption of electricity, oil, propane, natural gas, and steam and hot water used by an activity were obtained from the defense energy information system (DEIS). These tapes are maintained by an office in NAVFAC, but that office was unable to provide the latest version from their system. However, the data were later obtained from the David W. Taylor Naval Ship Research and Development Centc located at the Naval Station at Annapolis, Maryland. Transportation information was extracted manually from hardcopy reports of the transportation cost report processing system. These data include number of vehicles/equipment, fuel consumed, and total cost for transportation services at each activity. Data were also hand-extracted from the minor construction and repair special projects data base, another NAVFAC system that supplied the number and cost of both operations and maintenance, and military-construction-funded minor construction projects at a station.

Information pertaining to the capacity and utilization of family and unaccompanied personnel housing at an activity was also only available in hardcopy form. The unaccompanied personnel housing asset report provided housing capacity data, but no utilization rates were available. The family housing management information system, however, tracked both housing capacity and utilization rates.

Although the majority of workload data was available through NAVFAC systems, some data were obtained through other sources. Supply information concerning receipts,

issues, and stockage came from the Naval Supply Systems Command (NAVSUP). These data were not complete for all UICs, however, because the hardcopy reports prepared annually are done only for a sample of Navy activities. As with much of the NAVFAC data, the supply information had to be extracted manually. Table 2 provides a summary of the types of workload data obtained, the system from which it was extracted, and the manner in which it was collected. The data described to this point were collected at the UIC level and directly inputted into the data base with a minimum of preprocessing effort.

Contracting Data. As anticipated, a complication to the estimating procedures is that the host activity often compensates for varying workloads and/or shortages of personnel by contracting for services (notably maintenance and construction related) outside the Navy. Thus, it was expected that relationships relating workload to the host end strength alone would be misleading unless the contracting effect could be included.

The quest for appropriate contracting data proved to be difficult because the Navy does not have a complete historical accounting system for contracted services at the UIC level. NAVFAC maintains a contractor information system, but meetings with the data base manager indicated that activity-level information on the amount of contracted services purchased was not available from this system. The Washington Headquarters Services and the acquisition management information system resident there also failed to produce the desired data. Copies of tapes for 10 years of data were obtained that listed all major contracts purchased by Navy activities. Unfortunately, contracted services are tracked through a purchasing office and the data cannot be tracked to a specific naval station or air station, a feature vital for the investigation. The Navy inventory of commercial or industrial activities available through OP-43 was also examined, but the system lacked historical information.

Systems such as SHORSTAMPS/NMRS were also considered, but were found inadequate. The shore required operational capabilities (SHOROC) system does track contracting information, but there is no historical file. Further, the contracting data in this system has not been verified as entirely accurate, according to data base managers.

A method to account for contracted services purchased by an activity was discovered using accounting mechanisms. This was achieved by using elements of expense (EE) that track the portion of operations and maintenance (O&MN) money expended by an activity for contracted services. This information was only available from the Navy Finance and Accounting Office in hardcopy form for FY 1979 and FY 1980; therefore, a proration scheme was developed to estimate the portion of total O&MN dollars going for contracting in 1976 through 1978. This was done by taking total O&MN funding for the activity, also obtained from the same office in hardcopy form, for 1976 through 1980 and determining the portion contracted out in 1979 and 1980 using the EEs available for those years. This ratio was then applied to 1976 to 1978 data to produce figures for contracted services for those 3 years. This information was combined with total military construction (MCON) funding for each activity, available for 1976 to the present. Essentially all of the MCON appropriation is contracted out, according to Navy financial sources, so the combination of this and the contracting portion of O&MN represents all contracts purchased by an activity. The results of using this contracting variable in the investigation are described subsequently in this report.

Proration of PWC Support. In addition to contracted services provided by non-Navy sources, it was also necessary to account for the services performed by public works centers (PWCs) for the BOS host activities. There is no central data system available that can supply this type of data at the activity level. Initially, PWC manpower was prorated in proportion to the size of the activities that it most likely supported; this proration used

Table 2

Workload Data Collected with Data Base Source

Data	Data Source	Comments
<u>Facilities Information</u>:		
Acreage Amount of building space Number of buildings	Navy facilities assets data base	Tapes
<u>Transportation Information</u>:		
Number of vehicles Fuel consumed Total cost for transportation	Transportation cost report processing system	Manually extracted
<u>Minor Construction</u>:		
Number minor construction projects--O&MN/MCON Total cost minor construction projects--O&MN/MCON	Minor construction and repair special projects data base	Manually extracted
<u>Energy Information</u>:		
Electricity Steam and hot water Oil Propane and natural gas	Defense energy information system	Tapes
<u>Housing</u>:		
Unaccompanied personnel housing capacity	Unaccompanied personnel housing asset report	Manually extracted
Family housing capacity Family housing utilization	Family housing management information system	Manually extracted
<u>Supply Data Information</u>:		
Supply line items carried Supply receipts Supply issues	Inventory control operations at supply distribution activities report	Manually extracted

base profiles, tenant population, and various summary functional factors to make the determination. These approximating procedures proved to have several disadvantages and, as a result, a special survey was developed in conjunction with the NAVFAC manager of the PWC management information system. This survey was administered to the nine PWCs, and requested specific information concerning the major recipients of their services, the amount and type of services provided, and the man-days of work expended. These data led to an improved proration scheme for determining PWC support given to individual BOS host activities. This, in turn, improved the statistical significance of the resultant equations.

Manpower and Forces Data. The final category of data necessary to complete the investigation was composed of manpower and forces data. All manpower data (in the form of yearly end strengths) for BOS hosts, their tenants, and ship and aircraft forces came from the Navy cost information system (NCIS). The tenants at a specific host activity were identified from two sources. One source was supplied by OP-44, who in July 1980 conducted a survey of all BOS host activities and obtained a listing of their tenants. Copies of each of the surveys were obtained and a consolidated listing was developed and transferred to tape for processinng. This list was then matched with the NCIS data to produce tenant population variables for each host. A number of difficulties arose. First, a number of mismatches occurred because some of the UICs reported to be tenants did not exist in the NCIS file. Second, there were many instances where the same tenant was listed under many hosts. This happened for a large centralized activity such as a Regional NAVFAC Engineering Command, which actually consists of a main body of personnel at one location with many smaller detachments scattered over the region. Third, the OP-44 list contained both shore-based and force tenants. It was necessary to discard the force tenants data because more accurate data on the home base of aircraft and ship forces were already available.

Although substantial effort was expended in solving these host-tenant data problems and automating the calculation of tenant variables, the statistical analysis that followed produced discouraging results. Consequently, an alternative host-tenant listing provided by NAVFAC was tried next. This produced no better results and was not entirely appropriate, in that NAVFAC defined a host on the basis of property ownership rather than as provider of services.

These difficulties were reported to OP-44 who, in the meantime, had discovered and rectified some of the problems that were described. With an improved list, together with some further enhancements, the tenant variables were recalculated. The military tenant population was then found to be a significant driver of the host manpower, particularly at the naval stations. Despite the encouraging results, it is believed that the host-tenant listings can be further improved. OP-44's assistance would be especially important in developing tenant listings for foreign stations, which were excluded from the initial survey.

Although the NCIS file provided manpower associated with ship and aircraft forces, it was necessary to link these forces to the specific activities covered by our BOS groupings. In addition, the mix of the complexity of these forces together with force deployment patterns had to be considered. For ship forces, complexity data, focusing on displacement, generating capacity, and shaft horsepower, were available on tapes supplied by the Philadelphia Naval Shipyard. Homeporting and actual ship location information was found in the operations scheduling (OPSCHED) data from OP-643 and was provided through their supporting systems contractor. Data tapes were also obtained from the ship management information system (SMIS) from OP-902, but the SMIS data were not useful for homeport information because of the lack of historical files.

In the search for corresponding data for aircraft forces, a major obstacle was encountered due to the security classification of the data. Aircraft complexity data are available on tape for both current and historical time frames, but the information is classified. A model based on classified data would most probably be classified also, creating an impractical situation for users of the model. However, comparable unclassified data for aircraft complexity were found, in current and historic copies of Jane's Book of World Aircraft, and extracted with considerable effort. This included measures such as maximum weight, pounds of thrust, and number of engines. Also, homeporting and location data for aircraft were obtained from OPNAV.

Data Preparation

After all necessary data were located and collected, the information was prepared for processing. All hand-extracted files were key punched and transferred to tapes or were directly entered into the system to be used for analysis. A summary listing of all variables used in the analysis is found in Table 3.

A data base management package (EASYTRIEVE) was used to preprocess the data. For the most part, the preprocessing consisted of discarding irrelevant data and aggregating the remainder into a host-fiscal year formatted data base. As a result, the data base that was entered into the statistical analysis system (SAS) was relatively small for each BOS activity grouping.

There were two rather complicated preprocessing tasks. The first involved the manual input of the OP-44 host-tenant listings and the subsequent matching with the NCIS file to obtain tenant population variables. Second, the ship operating tempo data were provided in the form of annual tapes that did not have the same format. Since these data did not contain the actual UICs, ships were matched with NCIS on the basis of hull name, a process that was tedious and required careful examination. Programs were written to resolve these difficulties.

The data management capabilities of SAS were used to merge the component data sources--host characteristics, tenant populations, and force related data--into a unified data base suitable for statistical analysis.

Approach to the Analysis

The textbook approach for a modelling effort such as this is to (1) collect and organize all the relevant data, (2) analyze the data, (3) summarize the results, and (4) draw conclusions, in that order. In reality, however, there is an interweaving of tasks (1) and (2) because preliminary analysis of the data often leads to questions about the quality and completeness of the data itself. When this happens, some "backtracking" is required. Old data must be deleted and new data must be collected before further evaluation can proceed. This scenario was the reality for this effort. As stated previously, the early results caused a review and modification of the data with respect to tenant, contracting, and PWC measures. Even with consistent significant results for each of the groupings in the final analysis, the source data could be reviewed further for improvement. Also, some further review of the data is expected as the software for implementing the BOS model is constructed. User requirements as well as available data for the outyears will motivate this review. Nonetheless, it is believed that the major drivers of BOS manpower requirements have been identified and that the estimating relationships will prove to be useful tools for their intended purpose--long-range aggregate manpower forecasting based upon user-supplied force-level scenarios. The general approach and strategy that led to the final selection of variables is outlined in the following paragraphs.

Table 3

Summary Listing of all Variables

Variable	Type	Length	Position Format	Informat Label
ACRES	NUM	8	512	Total acres of land (NFADB)
AIRES	NUM	8	632	End strength (ES) of homeported squadrons
AREA	NUM	8	232	Square foot building space at base 80 (FADB)
AVGDIS	NUM	8	488	Average light displacement of ships in port
AVGMAN	NUM	8	456	Average ship ES visiting station each year
CONTRACT	NUM	8	17	Contractor dollars 79-80
CUSTMP	NUM	8	696	PWC major customer ES
DEP	NUM	8	496	Dependent population (DBFR)
ELEC	NUM	8	256	Electricity consumed at base in 1000KW
EMPTYWT	NUM	8	592	Weight of NAS-based aircraft (no load)
ES	NUM	8	248	Base end strength by year (NCIS)
FY	NUM	8	9	Fiscal year
HMES	NUM	8	424	Ship ES for homeported ships
HMWTES	NUM	8	368	Ship ES weighted (WTED) by homeport data
HOMDIS	NUM	8	336	Ship LT displacement WTED by homeport data
HOMFD	NUM	8	344	Ship full displacement WTED by homeport data
HOMGC	NUM	8	352	Ship primary general capacity WTED by home-port data
HOMHP	NUM	8	360	Ship total shaft horsepower WTED by homeport data
HPDAYS	NUM	8	432	Total days ships are homeported
LAND	NUM	8	304	Acreage at base (DBFR)
LOCATION	CHAR	18	38	Base location as appears in OPSCHED data
MAVGIN	NUM	8	128	Mean transportation average inventory 77-80
MAXWT	NUM	8	600	Weight of NAS-based aircraft (full load)
MBSPACE	NUM	8	120	Mean bach. housing spaces 78-82 (NAVFAC)
MCON DOL	NUM	8	520	MILCON expenditures
MES	NUM	8	216	Mean base end strengths 75-80 (NCIS)
MFSPACE	NUM	8	104	Mean family housing spaces 76-80
MFUTIL	NUM	8	112	Mean family housing utilization (NAVFAC)
MISSUES	NUM	8	192	Mean total supply issues 76-80 (NAVFAC)
MITEMS	NUM	8	208	Mean total stock items 76-80 (NAVFAC)
MNOMCON	NUM	8	168	Mean number MILCON-funded projects 75-80
MNOOMN	NUM	8	152	Mean number OMN-funded projects 75-80
MRECPTS	NUM	8	200	Mean total supply receipts 76-80
MREQ	NUM	8	184	Mean total material requests 76-80
MTOMCON	NUM	8	176	Mean total MILCON 75-80 (NAVFAC)
MTOOMN	NUM	8	160	Mean total OMN 75-80 (NAVFAC)
MTOTRAN	NUM	8	144	Mean total transportation 77-80
MWORKUN	NUM	8	136	Mean transportation work units 77-80 (NAVFAC)
NASUIC	CHAR	8	656	Naval air station unit identification code
NOBLDGS	NUM	8	224	Number of base buildings 80 (FADB)
NOPROPS	NUM	8	624	Number of propeller aircraft

Table 3 (Continued)

Variable	Type	Length	Position Format	Informat Label
NOTURBO	NUM	8	608	Number of turbo jets
NSUIC	CHAR	8	664	Naval station unit identification code
OMN DOL	NUM	8	528	OM&N expenditures
PEAKDIS	NUM	8	480	Peak light displacement of ships in port
PEAKMAN	NUM	8	448	Peak ship ES visiting station each year
POPSUP	NUM	8	320	Population supported at base (DBIK)
PWC	NUM	8	30	Public works center ES (NCIS)
PWCDUM	NUM	8	328	Indicates presence of PWC at base
PWCREV	NUM	8	680	PWC annual revenues (major customers)
PWCTOT	NUM	8	688	PWC annual revenues (all customers)
PWCUIC	CHAR	5	25	Public works center UIC
RATE	NUM	8	568	% PWC support to host (major customers)
RATE EE	NUM	8	536	% OMN dollars for contracting
RETIRE	NUM	8	504	Number of retirees (DBFR)
SHW	NUM	8	264	Steam and hot water consumed at base
SMES	NUM	8	384	Ship ES for all ships visiting port
SMPORT	NUM	8	376	Total days in port for visiting ships
SMWTES	NUM	8	240	Ship ES WTED by days in port
SUMDIS	NUM	8	272	Ship LT displacement WTED by days in port
SUMFD	NUM	8	280	Ship full displacement WTED by days in port
SUMGC	NUM	8	288	Ship primary general capacity WTED by days in port
SUMHP	NUM	8	296	Ship total shaft horsepower WTED by days in port
TENALL	NUM	8	544	Population of shore tenants
TENCIV	NUM	8	560	Civilian component of TENALL
TENMIL	NUM	8	552	Military component of TENALL
TITLE	CHAR	40	56	UIC title (NCIS dictionary)
TOTAREA	NUM	8	704	PWC major customer square foot building space
TOTES	NUM	8	464	Base end strength plus PWC manpower
TOTFD	NUM	8	400	Total ship full displacement (homeport data)
TOTGC	NUM	8	408	Total ship general capacity (homeport data)
TOTLBST	NUM	8	616	Total pounds of thrust (turbos)
TOTLD	NUM	8	392	Total ship light displacement (homeport data)
TOTPOP	NUM	8	312	Total population at base (DBFR)
TOTSHP	NUM	8	416	Total ship shaft HP (homeport data)
TRATE	NUM	8	576	% PWC support to host (total)
TWPWC	NUM	8	584	Prorated PWC ES (total rev)
TWTOTES	NUM	8	640	ES+TWPWC
TYPE	CHAR	8	96	Mathtech module
UIC	CHAR	5	4	Base unit identification code
WPWC	NUM	8	440	Prorated PWC ES (major customer rev)
WTOTES	NUM	8	472	ES+TWPWC

The statistical analysis system (SAS) software package was used to maintain and examine the source data. The ability to distinguish the components within a BOS grouping (for example, reserve air stations versus training air stations) was preserved. The observations within a given grouping consisted of data collected at the activity level over a 5-year period of time. These yearly observations were pooled; time series analysis was ruled out because of the limited historical data.

Missing values for certain data elements were a troublesome problem. Activities located on foreign soil tended to be incomplete in this regard. The approach finally adopted was to concentrate on identifying the candidate set of independent variables that would play a role in the final equations. This sometimes required the temporary dropping of observations for which key elements were missing. The objectives were to identify the relevant drivers of BOS manpower and then to fill the gaps where necessary rather than to seek more exhaustive information about variables that on initial analysis proved to be of no value.

It was expected to determine, for each BOS grouping, the parameters defined by a functional relationship:

$$MP = F(SIZE, TENANTS, FORCES)$$

The variables in this representation are used generically. SIZE is one or more variables that describe the physical size of the activity (number of buildings, acreage, number of housing spaces, etc.). TENANTS refers to the size of the shore-based population supported by the BOS activity. FORCES represents a measure of the size and complexity of the ship forces (for naval stations) and aircraft forces (for air stations) that impose a workload upon a host BOS activity. The many alternative measures for FORCES, some based upon homeporting and others based upon actual presence at the host activity, were discussed earlier.

It was assumed that the parameters underlying the above formulation are constant over time. This assumption was later validated by the data itself. On the other hand, one could argue (and subsequent analysis substantiates) that there are significant differences in requirements from host to host that would seem to justify activity specific adjustments to the regression model. It was felt that this procedure was fundamentally contrary to the basic meaning of an aggregate model; indeed, the inclusion of such activity-specific adjustments will result in no change in the predicted values over all activities in the sample.

MP is the dependent variable representing manpower at the host and is, in the case of naval stations and air stations, the sum of the actual end strength at the host plus that portion of the PWC end strength that approximates the support given to the host.

Representation of the contracting effect proved to be more difficult than anticipated. Although estimates of the MCON and O&MN appropriations used for acquiring contracted services were obtained, the nature of the data is such that they cannot be used to determine (even approximately) how much manpower was purchased with these funds. Thus, statistical techniques were used to estimate the contribution of services contracted by each station.

Another strategy used in screening candidate variables was to group them homogeneously, according to prior beliefs of their relationship to manpower. In this way, it could be detemined which variables are statistically equivalent to each other, and the best combination of variables for each BOS grouping could be obtained. As an example, the

manpower, total displacement tonnage, and generating capacity of all ships homeported at a given location were found (not surprisingly) to be highly correlated with each other. Statistically, then, one of the above variables could be used just as well as another. Practical considerations during software implementation may give preference to tonnage over generating capacity, since tonnage would be expected to be more readily available in the future for ships under construction.

Both linear and nonlinear functional forms for the regression analysis were attempted. The exponential forms yielded no better results than the linear relationships and are inherently no more justifiable; thus, the simpler linear form was adopted.

RESULTS

Naval Station Results

Based on preliminary investigation, a number of candidate variables were dropped from further consideration. The supply and transportation related variables were excluded by virtue of their incompleteness; others were dropped because of altogether meaningless correlations with the end strength variables. The remaining variables were divided into the following groups to simplify further analysis.

1. Facility Size Measures:

    a. AREA--Square footage of building space.
    b. MBSPACE--Mean number of bachelor housing spaces.
    c. NOBLDGS--Number of buildings.

2. Tenant Data:

    a. TENALL--Total population of shore tenants.
    b. TENCIV--Civilian component of TENALL.
    c. TENMIL--Military component of TENALL.

3. Ship Forces Weighted by Days in Port:

    a. SMWTES--On board end strength.
    b. SUMDIS--Light displacement.
    c. SUMFD--Full displacement.
    d. SUMHP--Total shaft horsepower.
    e. SUMGC--Primary generating capacity.

4. Ship Forces for Homeported Ships:

    a. HMWTES--On board end strength.
    b. HOMDIS--Light displacement.
    c. HOMFD--Full displacement.
    d. HOMHP--Total shaft horsepower.
    e. HOMGC--Primary generating capacity.

The pairwise correlations of WTOTES (station end strength plus a prorated portion of PWC end strength) within each group are displayed in Appendix B. As expected, the intercorrelations within Groups 3 and 4 are extremely high. As a result, no more than one variable from each group was expected to be included in the final equation. There are

two distinct categories of FORCE variables (Groups 3 and 4) because it was plausible that they each make a contribution--Group 3 in capturing the actual ship activity at a port and Group 4 in representing the services for dependents of homeported personnel regardless of deployment.

In finding the "best" combination of variables for estimating station manpower, a combination of statistical and common sense criteria was used. The goal was not only to explain a reasonable amount of variation in the dependent variable, but also to avoid extensive multicollinearity and the use of variables that would be impossible to project or estimate in the future. These considerations led to the following equation for naval stations:

$$\text{WTOTES} = .064\ \text{AREA} + .[illegible]\ \text{TENMIL} + .107\ \text{SMWTES} - 228.8$$
$$(2.6[illegible]) \quad ([illegible]) \quad (5.06)$$
$$\text{Critical } t\text{-value } (\alpha = .05) = 1.68.$$

The corresponding t-values of each coefficient are listed parenthetically. The overall fit is measured bv an r^2 value of .84 and an F-value of 74.09 (significance probability of .0001). The coefficient of variation is .2[illegible]. Thus, 84 percent of the variance is explained by this equation and all variable coefficients are significant. The significance of the military tenant population has decreased with the presence of SMWTES since the pairwise correlation of the two variables is 0.78. Nonetheless, this represents the best possible predictive equation, given constraints concerning the intuitive appeal of the independent variables. Care must be taken, however, in using individual coefficients as representative of the marginal impact of a single variable. In making realistic forecasts, it is unreasonable to project increased workload caused by increased force levels without also projecting an increase in the tenant population. It is the combined effect of those changes that is measured by the estimating relationship.

The variables included in this relationship are intuitively appealing in that AREA is representative of the size of the physical plant that is maintained by the host, whereas TENMIL and SMWTES capture the size of the military personnel for whom services (housing, medical care, and the like) are provided.

The addition of a variable representing the size of the homeported population was thought to be desirable, since it would serve as a proxy for the dependent population resident at the host regardless of actual deployment patterns. Unfortunately, this variable entered the equation in combination with SMWTES with a negative coefficient. Homeported end strength (HMES) could be substituted for SMWTES and yield almost as good a fit overall, but residuals were poor for those locations that are not designated as homeports since the ship activity at these sites would not be captured at all with this variable.

Having obtained a reasonable predictive equation, the hypothesis that contracting outside of the Navy for some BOS services had a significant relation to the prediction errors was examined. As a first step, the contracting variable was added as a possible independent variable in the regression analysis. While the correlation of WTOTES with contracting was highly significant, it was in the wrong direction; its use as a predictor was therefore meaningless. This positive correlation is believed to be a result of scaling problems--the larger the station, the more it contracts in absolute terms. The contracting variable was rescaled on the basis of total building area and tenant population and these normalized variables were introduced into the regression analysis and examined with respect to their relationship to residuals. The conclusion, based upon contracting data collected, is that there is no relationship between the residuals in the model and the measurements of individual activity contracting.

The number of observations upon which the naval station equation is derived deserves note. Seven of the 16 candidate naval stations were dropped because of the absence of meaningful tenant data for foreign stations. Thus, the regression equation is based upon a sample of 45 observations, consisting of 9 stations observed over a 5-year period. OP-44 is aware of this problem and has agreed to assist in developing suitable host-tenant relationships for the foreign bases.

Additionally, it was found that the methodology for estimating ship workload proxies resulted in low estimates, particularly for Guantanamo and Midway Island. Subsequent investigation revealed that all records of refresher training exercises were classified as a not-in-port activity. This was a serious omission at Guantanamo, since refresher training is a major activity of ships at that base. Nonetheless, this problem is believed to be solvable and OP-44 has again agreed to contribute their knowledge of individual BOS activities to improving the source data used in this analysis. With these modifications, the results for naval stations could be improved.

The residual plot shown on page B-5 shows no discernible pattern other than the expected feature that a given station is consistently under- or overestimated across all years. This is because the greatest variation in the host end strength results from variation between stations rather than variations for a given station across time.

As a further check on the homoscedasticity (constant variance of the error term) assumption inherent in an ordinary least squares regression, the residuals were correlated with various measures of the "size" of the activity. No significant relationships were found. Also, interaction terms were introduced into the regression equation but they added no additional explanatory power.

Air Stations Results

Data supplied by NAVFAC was more extensive for air stations than for naval stations, particularly with regard to information on transportation and supply. After the initial screening, the remaining variables were placed into homogeneous groups:

1. Facility Size Measures:

   a. AREA--Square footage of building space.
   b. MBSPACE--Mean number of bachelor housing space.
   c. MAVGIN--Mean inventory of vehicles maintained.
   d. ELEC--Electricity consumed at base (1000kw).
   e. MTDTRAN--Mean dollars for transportation.

2. Tenant Data:

   a. TENALL--Total population of shore tenants.
   b. TENCIV--Civilian component of TENALL.
   c. TENMIL--Military component of TENALL.

3. Air Force Measures:

   a. AIRES--End strength of home-based squadrons.
   b. EMPTYWT--Empty weight of home-based aircraft.

The other complexity measures for aircraft (pounds of thrust, number of turbojets or props, etc.), showed no relationship to air station end strength. The correlations of

WTOTES with the variables within each group are shown in Appendix C. Early analysis showed that these relationships were not significantly different at the reserve or training air stations than at the fleet air stations. This was consistent with the contention of OP-44, who suggested that requirements at the host activity should bear little relationship to the specialized mission of the activity.

Using the criteria established for naval stations, the best predictive equation for air stations is:

$$\begin{gathered} \text{WOTES} = .015\ \text{AREA} + .096\ \text{AIRES} + .116\ \text{TENALL} + 367.70 \\ (4.64) \quad (8.01) \quad (9.42) \\ \text{WTOTES} = \text{Critical t-value } (\alpha = .05) = 1.68. \end{gathered}$$

This equation was based upon complete sets of data for 25 air stations over a 5-year period. The overall r^2 value is 0.83 with a coefficient of variation equal to .23. In this case, the presence of all three variables is extremely significant. AREA and TENALL do have an intercorrelation of .72. An equation using MBSPACE and MAVGIN in place of AREA would eliminate this problem but the ability to interpret those variables is questionable. Tests for heteroscedasticity and the presence of significant interaction terms were conducted but did not lead to any modification of the results.

Separate analysis for each type of station and the use of dummy variables to distinguish these types resulted in no improvement. The analysis of residuals showed that the equations predicted equally well for reserve air stations and training air stations. The residual plot is displayed on page C-4. Again, the absence of tenant data for foreign air stations is a drawback that could be rectified with the help of OP-44.

CONCLUSIONS

The feasibility of developing statistical models to forecast BOS manpower requirements for naval stations and air stations at the aggregate level has been demonstrated. It is concluded that, for these categories of activities, manpower requirements are functionally related to the total population supported as well as to force-related variables. As the total population supported by these BOS categories or the force level increases, BOS manpower requirements increase.

Further, it is concluded that the most appropriate use of these equations is to estimate aggregate BOS manpower requirements 5 to 15 years in the future. That is, the equations by themselves provide best estimates of total manpower requirements for groupings of BOS activities. Such aggregate estimates are most suitable in a long-range planning context; usually there are too many uncertainties in the basic inputs to permit accurate forecasting at very detailed levels. In long-range planning, it is much more important to be able to accurately estimate major, first-order effects of alternative programs. The BOS equations developed here satisfy that kind of need.

Notwithstanding the intended use of these estimating equations, it is possible to consider using the equations for activity-specific analysis of near-term issues. As previously discussed, the equations were developed from data collected at the activity level. However, there was substantial variation of certain individual stations from the regression equation (i.e., certain stations had larger residuals than others). Thus, using the equations to make zero-based estimates for these stations would produce high variance results. However, if the user were willing to estimate only the <u>direction of change</u> or the <u>approximate magnitude</u> of change at a given station due to changed input

variables, then the equations might produce acceptable results. On the other hand, if it was desired to have an approximate estimate of manpower requirements for a new base (i.e., one for which there is no historical experience), then the equations might be used to provide a first estimate.

In all of these activity-specific cases, however, the user should be aware of the likely error of the estimate. It is a mathematical fact that, in relative terms, this error will be greater for activity-specific estimates than it will be for the aggregate estimate. The equations produced by this research effort were developed to satisfy quality criteria related to a useful aggregate model. There is no implied guarantee that such equations by themselves will produce comparable, acceptably accurate estimates at the activity level.

The most important value of the equations at this juncture is their ability to identify the specific measures most relatable to BOS manpower requirements. In particular, prior expectation that these requirements are dependent upon some measure of the total population supported as well as force-related variables was confirmed. To improve these results, it will be necessary to obtain the missing data for tenants at foreign stations and to correct the ship activity data for the omission of refresher training. The effort involved to accomplish these tasks appears to be justified by the past, observed improvement in the equations that resulted from the revised PWC proration scheme.

Additionally, it is anticipated that Navy manpower planners can benefit from the data base created in this effort. In particular, the historical data bases representing ships in port by location, squadron aircraft homebasing, and distribution of PWC support to Navy activities in a given locale have high potential to support other investigations.

The BOS model resulting from this investigation will be implemented in an interactive computer environment provided by OP-01 users (OP-120 specifically). The computer programs would take into consideration the relationship of the equations to each other as well as the impacts of policy variables on the BOS manpower requirements. When appropriate computer resources are identified in OP-44, the BOS model and its comprehensive data base will be implemented for operational use in that organization.

APPENDIX A

END STRENGTHS OF BOS ACTIVITIES

End Strengths of BOS Activities

Activity	Officers	Enlisted	U.S. Civilians	Foreign Civilians
	1979 End Strength			
Naval Stations				
Naval Stations, Atlantic				
NAVSTA Roosevelt Roads, PR	43	994	590	---
NAVSTA Guantanamo, Cuba	31	666	137	552
NAVSTA Norfolk, VA	33	915	481	---
NAVSTA Charleston, SC	17	499	268	---
NAVSTA Mayport, FL	23	329	392	---
NAVSTA Rota, Spain	55	681	80	972
NAVSTA Keflavik, Iceland	62	569	49	768
NAVSTA Annapolis, MD	15	318	--	---
NAVSTA Panama	26	77	69	175
NAVPHIBASE Little Creek, VA	28	330	425	---
NAVSUBASE New London, CT	23	278	512	---
Naval Stations, Pacific				
NAVSTA San Diego, CA	30	630	333	---
NAVSTA Guam, MI	15	155	273	---
NAVSTA Subic Bay, PI	19	504	23	380
NAVSTA Pearl Harbor, HI	25	606	507	---
NAVSTA Adak, AL	26	544	142	---
NAVSTA Midway Island	10	300	---	---
NAVSTA Long Beach, CA	26	312	179	---
NAVPHIBASE Coronado, CA	17	330	129	---
NAVSUBASE Bangor, WA	27	145	---	---
NAVSUBASE Pearl Harbor, HI	9	130	160	---
Naval Air Stations				
Naval Air Stations, Atlantic				
NAS Norfolk, VA	40	844	695	---
NAS Jacksonville, FL	61	868	1164	---
NAS Key West, FL	32	721	438	---
NAS Guantanamo, Cuba	23	355	5	16
NAS Brunswick, ME	36	414	334	---
NAS Oceana, VA	45	705	542	---
NAS Cecil Field, FL	55	792	528	---
NAS Bermuda	34	488	195	152
NAF Mildenhall, UK	7	50	2	5
NAF Lajes, Azores	3	81	1	50
NAF Sigonella, Sicily	44	678	52	1023

Activity	Officers	Enlisted	U.S. Civilians	Foreign Civilians
	1979 End Strength			
Naval Air Stations (continued)				
Naval Air Stations, Pacific				
NAS North Island, CA	51	1001	1111	---
NAS Alameda, CA	31	465	937	---
NAS Moffett Field, CA	34	485	404	---
NAS Barber's Point, HI	32	543	261	---
NAS Whidbey Island, WA	40	590	627	---
NAS Miramar, CA	47	841	612	---
NAS Fallon, NV	24	525	535	---
NAS Agana, Guam	26	517	101	---
NAS Cubi Point, PI	43	887	26	439
NAS Lemoore, CA	45	629	560	---
NAF Misawa, Japan	19	352	3	140
NAF Atsugi, Japan	23	334	18	562
NAF El Centro, CA	---	126	152	---
Naval Air Training Stations				
NAS Saufley Field, FL	--	22	---	---
NAS Pensacola, FL	32	421	888	---
NAS Corpus Christi, TX	30	270	658	---
NAS Memphis, TN	32	505	486	---
NAS Kingsville, TX	19	206	270	---
NAS Chase Field, TX	22	175	317	---
NAS Whiting Field, FL	20	237	302	---
NAS Meridian, MS	20	235	293	---
Reserve Air Stations				
NAS South Weymouth, MA	23	302	217	---
NAS Willow Grove, PA	31	408	251	---
NAS Atlanta, GA	22	244	122	---
NAS New Orleans, LA	28	382	215	---
NAS Dallas, TX	27	375	225	---
NAS Glenview, IL	26	355	220	---
NAF Washington, DC	29	343	160	---
NAF Mt. Clemens, MI	18	186	72	---

APPENDIX B

CORRELATIONS AND RESIDUALS--NAVAL STATIONS

Correlations of NAVSTA End Strength with Size Variables

CORRELATIONS WITH GROUP I 5

VARIABLE	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
WTOTES	80	1054.27826961	620.08973806	84342.26156900	15.00000000	2197.81130327
AREA	80	8466.30700000	3522.14806417	677304.56000000	3720.26400000	18411.66600000
MBSPACE	80	1564.36250000	907.73030964	125149.00000000	86.60000000	3467.60000000
NOBLDGS	80	1171.93750000	700.52507149	93755.00000000	376.00000000	3134.00000000

CORRELATION COEFFICIENTS / PROB > R UNDER HO:RHO=0 / N = 80

	WTOTES	AREA	MBSPACE	NOBLDGS
WTOTES	1.00000	0.45887	0.52506	0.17189
ES+TWPWC	0.0000	0.0001	0.0001	0.1274
AREA	0.45887	1.00000	0.35694	0.65398
SQ. FT. BUILDING SPACE AT BASE 80 (FADB)	0.0001	0.0000	0.0012	0.0001
MBSPACE	0.52506	0.35694	1.00000	0.00187
MEAN BACH HOUSING SPACES 78-82 (NAVFAC)	0.0001	0.0012	0.0000	0.9869
NOBLDGS	0.17189	0.65398	0.00187	1.00000
NO. OF BASE BUILDINGS 80 (FADB)	0.1274	0.0001	0.9869	0.0000

Correlations of NAVSTA End Strength with Tenant Variables

CORRELATIONS WITH GROUP II

VARIABLE	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
WTOTES	80	1054.27826961	620.06973606	84342.26156900	15.00000000	2197.81130327
TENALL	45	7732.04444444	4643.32989619	347942.00000000	855.00000000	14539.00000000
TENMIL	45	2560.88888889	1737.97931547	115240.00000000	400.00000000	6272.00000000
TENCIV	45	5171.15555556	3530.42029403	232702.00000000	224.00000000	9885.00000000

CORRELATION COEFFICIENTS / PROB > R UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

	WTOTES	TENALL	TENMIL	TENCIV
WTOTES ES+TWPWC	1.00000 0.0000 80	0.57209 0.0001 45	0.86433 0.0001 45	0.32693 0.0284 45
TENALL POPULATION OF SHORE TENANTS	0.57209 0.0001 45	1.00000 0.0000 45	0.75076 0.0001 45	0.94565 0.0001 45
TENMIL MILITARY COMPONENT OF TENALL	0.86433 0.0001 45	0.75076 0.0001 45	1.00000 0.0000 45	0.49513 0.0005 45
TENCIV CIVILIAN COMPONENT OF TENALL	0.32693 0.0284 45	0.94565 0.0001 45	0.49513 0.0005 45	1.00000 0.0000 45

Correlations of NAVSTA End Strength with Ship Activity Variables

CORRELATIONS WITH GROUP III

VARIABLE	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
WTOTES	80	1054.27826961	620.08973806	84342.261569	15.0000000	2197.8113033
SMWTES	80	2637.34719178	3338.14298677	210987.775342	0	14168.6958904
SUMDIS	80	98914.94537671	131672.14182893	7913195.630137	0	503446.8630137
SUMFD	80	150732.61698630	204729.26975220	12058609.358904	0	798265.5945205
SUMGC	80	51886.60270548	72529.09886127	4150928.216438	0	291960.1643836
SUMHP	80	549557.69143835	708740.26358976	43964615.315068	0	2431143.8356164

CORRELATION COEFFICIENTS / PROB > R UNDER HO:RHO=0 / N = 80

	WTOTES	SMWTES	SUMDIS	SUMFD	SUMGC	SUMHP
WTOTES ES+TWPWC	1.00000 0.0000	0.55555 0.0001	0.52036 0.0001	0.52936 0.0001	0.53317 0.0001	0.51013 0.0001
SMWTES SHIP MANPOWER WEIGHTED BY DAYS IN PORT	0.55555 0.0001	1.00000 0.0000	0.95021 0.0001	0.93975 0.0001	0.93267 0.0001	0.96458 0.0001
SUMDIS SHIP LT DISPLCMNT WTED BY DAYS IN PORT	0.52036 0.0001	0.95021 0.0001	1.00000 0.0000	0.99743 0.0001	0.98774 0.0001	0.98730 0.0001
SUMFD SHIP FULL DISPLCMNT WTED BY DAYS IN PORT	0.52936 0.0001	0.93975 0.0001	0.99743 0.0001	1.00000 0.0000	0.98223 0.0001	0.98269 0.0001
SUMGC SHIP PRIMRY GEN CAP WTED BY DAYS IN PORT	0.53317 0.0001	0.93267 0.0001	0.98774 0.0001	0.98223 0.0001	1.00000 0.0000	0.97526 0.0001
SUMHP SHIP TOT SHAFT HP WTED BY DAYS IN PORT	0.51013 0.0001	0.96458 0.0001	0.98730 0.0001	0.98269 0.0001	0.97526 0.0001	1.00000 0.0000

Correlations of NAVSTA End Strength with Ship Homeporting Variables

CORRELATIONS WITH GROUP IV

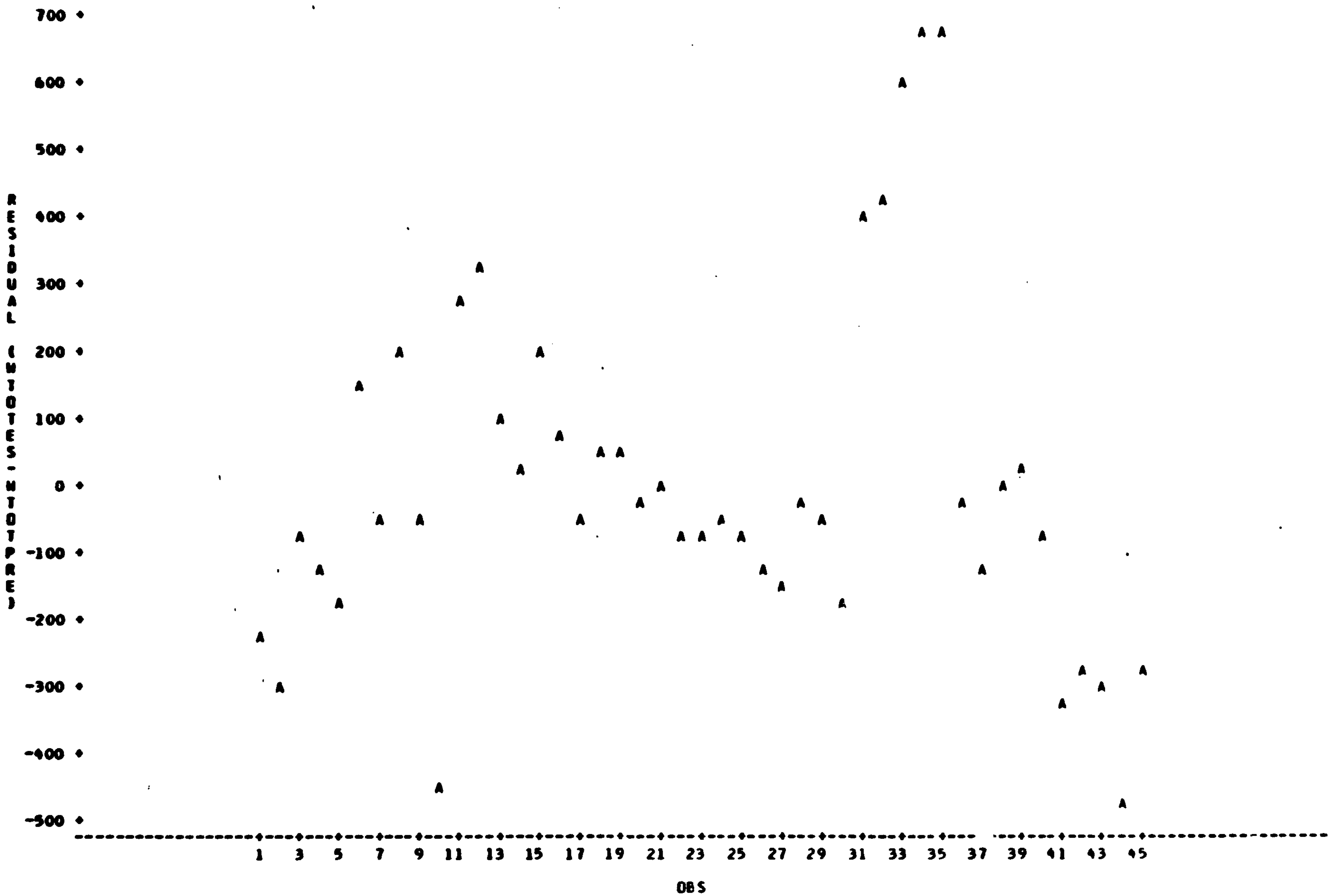
VARIABLE	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
WTOTES	80	1054.2782696	620.0897381	84342.26157	15.000000	2197.811303
HMWTES	65	11190.7031823	14050.3490142	727395.70665	0	45956.827397
HOMDIS	65	570189.9656059	765983.3967234	37062347.76438	0	2611891.460274
HOMFD	65	876470.1700316	1187931.0481835	56970561.05205	0	4155977.106849
HOMGC	65	306926.0652476	426519.8583627	19950194.24110	0	1625567.917808
HOMHP	65	3295920.5816649	4304686.2410073	214234837.60822	0	14153572.602740

CORRELATION COEFFICIENTS / PROB > R UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

	WTOTES	HMWTES	HOMDIS	HOMFD	HOMGC	HOMHP
WTOTES ES+TWPWC	1.00000 0.0000 80	0.63509 0.0001 65	0.62058 0.0001 65	0.61028 0.0001 65	0.62483 0.0001 65	0.61878 0.0001 65
HMWTES SHIP MANPOWER WTED BY HOMEPORT DATA	0.63509 0.0001 65	1.00000 0.0000 65	0.99080 0.0001 65	0.97907 0.0001 65	0.97861 0.0001 65	0.99464 0.0001 65
HOMDIS SHIP LT DISPLCMNT WTED BY HOMEPORT DATA	0.62058 0.0001 65	0.99080 0.0001 65	1.00000 0.0000 65	0.99577 0.0001 65	0.98928 0.0001 65	0.98899 0.0001 65
HOMFD SHIP FULL DSPLCMNT WTED BY HOMEPORT DATA	0.61028 0.0001 65	0.97907 0.0001 65	0.99577 0.0001 65	1.00000 0.0000 65	0.98253 0.0001 65	0.98005 0.0001 65
HOMGC SHIP PRIMRY GEN CAP WTED BY HOMPORT DATA	0.62483 0.0001 65	0.97861 0.0001 65	0.98928 0.0001 65	0.98253 0.0001 65	1.00000 0.0000 65	0.97302 0.0001 65
HOMHP SHIP TOT SHAFT HP WTED BY HOMEPORT DATA	0.61878 0.0001 65	0.99464 0.0001 65	0.98899 0.0001 65	0.98005 0.0001 65	0.97302 0.0001 65	1.00000 0.0000 65

RESIDUAL PLOT FOR ALL NAVAL STATIONS

PLOT OF WTOTRES*OBS   LEGEND: A = 1 OBS, B = 2 OBS, ETC.



APPENDIX C

CORRELATIONS AND RESIDUALS--NAVAL AIR STATIONS

Correlations of NAS End Strength with Size Variables

CORRELATIONS FOR GROUP I

VARIABLE	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
WTOTES	195	930.78940965	590.92475787	181503.93488	0	2663.5615078
AREA	170	12427.93658824	10558.82676509	2112749.22000	1815.0900000	44415.5280000
MBSPACE	175	1422.17714286	1201.12748830	248881.00000	60.2000000	6591.8000000
MTDTRAN	160	642628.61979167	362396.17076122	102820579.16667	60330.0000000	1325527.7500000
ELEC	162	37334.49382716	25461.57651246	6048188.00000	0	100968.0000000

CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

	WTOTES	AREA	MBSPACE	MTDTRAN	ELEC
WTOTES	1.00000	0.73903	0.53479	0.75793	0.58190
ES+TPWC	0.0000	0.0001	0.0001	0.0001	0.0001
	195	170	175	160	162
AREA	0.73903	1.00000	0.39379	0.54531	0.56971
SQ.FT. BUILDING SPACE AT BASE 80 (FADB)	0.0001	0.0000	0.0001	0.0001	0.0001
	170	170	165	150	160
MBSPACE	0.53479	0.39379	1.00000	0.44210	0.68477
MEAN BACH HOUSING SPACES 78-82 (NAVFAC)	0.0001	0.0001	0.0000	0.0001	0.0001
	175	165	175	155	162
MTDTRAN	0.75793	0.54531	0.44210	1.00000	0.60220
MEAN TOTAL $ TRANSPORTATION 77-80	0.0001	0.0001	0.0001	0.0000	0.0001
	160	150	155	160	145
ELEC	0.58190	0.56971	0.68477	0.60220	1.00000
ELECTRICITY CONSUMED AT BASE IN 1000KW	0.0001	0.0001	0.0001	0.0001	0.0000
	162	160	162	145	162

Correlations of NAS End Strength with Tenant Variables

CORRELATIONS FOR GROUP II

VARIABLE	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
WTOTES	195	930.78940965	590.92475787	181503.93488111	0	2663.58150779
TENALL	130	2285.20000000	2658.44041066	297076.00000000	0	9307.00000000
TENCIV	130	1319.14615385	2022.67369723	171489.00000000	0	7723.00000000
TENMIL	130	966.05384615	1298.75360830	125587.00000000	0	7053.00000000

CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

	WTOTES	TENALL	TENCIV	TENMIL
WTOTES ES*TPWC	1.00000 0.0000 195	0.80626 0.0001 130	0.83123 0.0001 130	0.35581 0.0001 130
TENALL POPULATION OF SHORE TENANTS	0.80626 0.0001 130	1.00000 0.0000 130	0.88074 0.0001 130	0.67526 0.0001 130
TENCIV CIVILIAN COMPONENT OF TENALL	0.83123 0.0001 130	0.88074 0.0001 130	1.00000 0.0000 130	0.24540 0.0049 130
TENMIL MILITARY COMPONENT OF TENALL	0.35581 0.0001 130	0.67526 0.0001 130	0.24540 0.0049 130	1.00000 0.0000 130

Correlations of NAS End Strength with Aircraft Activity Veriables

CORRELATIONS FOR GROUP III

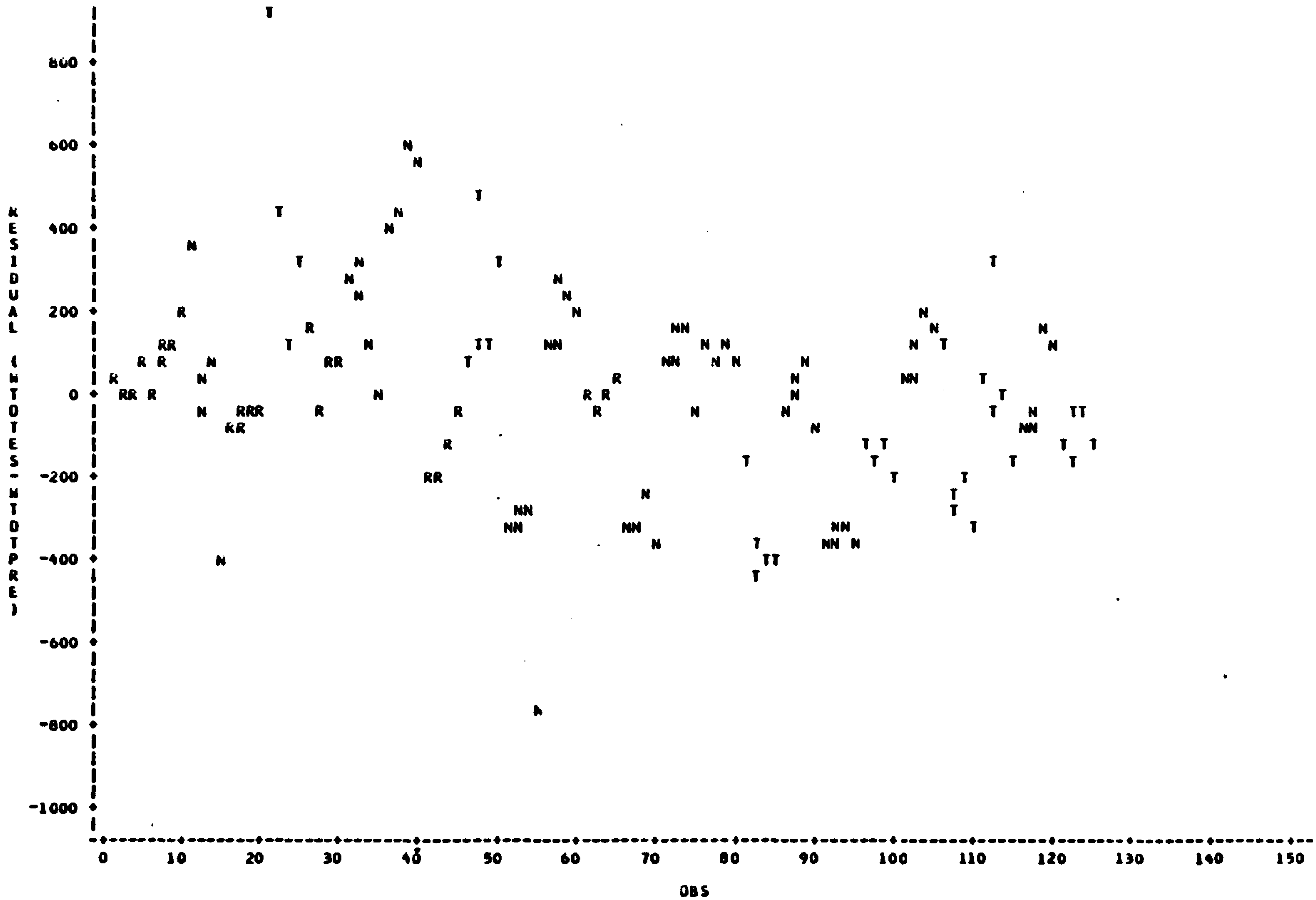
VARIABLE	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
WTOTES	195	930.7894096	590.9247579	181503.93488	0	2663.5815078
AIRES	160	2021.2437500	2095.1697662	323399.00000	0	7038.0000000
EMPTYWT	158	1645085.6139241	1784726.3273831	259923527.00000	29685.0000000	818[illegible]21.0000000

CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

	WTOTES	AIRES	EMPTYWT
WTOTES ES+TPWC	1.00000 0.0000 195	0.58545 0.0001 160	0.38964 0.0001 158
AIRES END STRENGTH OF HOMEPORTED SQUADRONS	0.58545 0.0001 160	1.00000 0.0000 160	0.88156 0.0001 158
EMPTYWT WEIGHT OF NAS BASED AIRCRAFT(NO LOAD)	0.38964 0.0001 158	0.88156 0.0001 158	1.00000 0.0000 158

RESIDUAL PLOT FOR ALL NAVAL AIR STATIONS

PLOT OF NTOTRES*OBS   SYMBOL IS VALUE OF TYPE



NOTE: 9 OBS HIDDEN

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